



*Draft*  
**Risk-Based End State Vision  
for  
Lawrence Livermore National Laboratory  
Livermore Site**  
*Version 2*



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Livermore Site Office  
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February 2004

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## **Acronyms and Abbreviations**

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CSM	Conceptual Site Model
DCE	Dichloroethylene
DOE	U.S. Department of Energy
DTSC	Department of Toxic Substances Control
EM	Environmental Management
FY	Fiscal Year
EPA	U.S. Environmental Protection Agency
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
MNA	Monitored natural attenuation
NNSA	National Nuclear Security Administration
PCB	Polychlorinated biphenyl
PCE	Tetrachloroethylene (perchloroethylene)
RBES	Risk-Based End State
ROD	Record of Decision
RWQCB	California Regional Water Quality Control Board
SVE	Soil vapor extraction
TCE	Trichloroethylene
VOC	Volatile organic compound

## **Executive Summary**

This Risk-Based End State (RBES) Vision for the Lawrence Livermore National Laboratory (LLNL) Livermore Site compares environmental site conditions and remedial strategies between the current and planned future use of the site. It is not a decision document. The Risk-Based End State Vision focuses on ensuring that the U.S. Department of Energy (DOE) cleanup strategy is driven by risk to human and ecological receptors. DOE recognizes that the End State Vision may not agree with existing site compliance agreements or regulations. If DOE ultimately decides to seek changes to the current compliance agreements, decisions, or statutory/regulatory requirements, those changes will be made in accordance with applicable requirements and procedures.

Future land use conditions described in this document consider a 20-year timeframe, typically used by governmental organizations to evaluate growth changes in terms of population and service needs. This provides a documented foundation for land use, exposure scenarios, and other aspects of risk assessment in this Risk-Based End State Vision document. The 20-year timeframe does not apply in any way to cleanup strategies and should not be inferred to indicate that DOE anticipates that cleanup will be discontinued in 20 years (or at any arbitrary time in the future).

This document includes standardized maps that show the Current State and Risk-Based End State for the physical and surface interface; human and ecological land use; land ownership; demographics; and hazards at regional, site-specific, and site-level scales. Conceptual Site Models show, in diagram form, information regarding the hazards, pathways, receptors, and barriers to exposure (current or planned) between the hazards and the receptors.

### **Site Background**

The primary mission of the Livermore Site is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide. Livermore Site programs include advanced defense technologies, energy, environmental sciences, biosciences, and basic science applied to the enhancement of national security. The Livermore Site is a contributor to the Stockpile Stewardship and Homeland Security programs.

During past Livermore Site operations, volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE), tritium, fuel hydrocarbons, and metals were released to the environment. Initial hazardous materials releases occurred in the mid- to late-1940s when the site was the Livermore Naval Air Station. There is also evidence that localized spills, unlined landfills, and leaking tanks and impoundments contributed contaminants to soil and ground water in the post-Navy era. VOCs and metals are present in ground water in concentrations above drinking water standards.

Environmental restoration activities at the Livermore Site are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The site was added to the CERCLA National Priorities List in 1987. The U.S. Environmental Protection Agency (EPA), the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) provide regulatory oversight. DOE is the lead agency for environmental restoration at the Livermore Site.

A Record of Decision (ROD) for the Livermore Site was signed in 1992 that specified that ground water would be remediated to Maximum Contaminant Levels (MCLs) both onsite and offsite.

The selected remedies for the Livermore Site cleanup consist of extracting and treating contaminated ground water and soil vapor. The Livermore Site cleanup has been expedited by implementing an Engineered Plume Collapse strategy, “smart” pump and treat, contaminant source isolation, portable treatment unit technology, and innovative remediation technologies such as catalytic reductive dehalogenation. Significant progress has been made in reducing the extent and concentrations of the ground water VOC plume that extended offsite to the west of the Livermore Site, and in controlling and reducing the concentrations and mass of onsite VOCs. The two CERCLA Five-Year Reviews have concluded that the existing remediation network continues to function as intended and is protecting human health and the environment.

### **Risk-Based End State Vision**

For this Risk-Based End State Vision, the individual contaminant release sites at the Livermore Site have been grouped into a single Hazard Area. This document evaluates a number of factors relevant to the implementation of a Risk-Based End State at the Livermore Site, including:

- Physical and Surface Interface.
- Human and Ecological Land Use.
- Legal Ownership.
- Demographics.
- Primary and Secondary Contaminant Sources.
- Release, Transport, and Exposure Mechanisms.
- Temporary Barriers or Controls.
- Remediation, Mitigation, and Other Intervention.

Three exposure scenarios are described and compared:

1. **Current State** – Conditions at the Livermore Site in 2003. The DOE Office of Environmental Management (EM) is now responsible for cleanup activities. After EM mission completion (anticipated to occur at the end of Fiscal Year [FY] 2006) oversight of cleanup will be transferred to the National Nuclear Safety Administration (NNSA).
2. **Current Cleanup Baseline End State** – The end state the site will be in after implementing the existing cleanup strategy. This is based on the requirements in current baseline work plan documents, compliance agreements, including the 1992 Record of Decision for the Livermore Site, and environmental regulations. The timeframe for implementing the remedial actions required to achieve this end state is the current EM mission completion date for the Livermore Site (FY 2006). At the Livermore Site, these remaining remedial actions include installing several additional ground water and soil vapor extraction and treatment facilities. However, cleanup activities will continue after EM mission completion (e.g., long-term ground water extraction). At the Livermore Site, compliance documents currently specify that ground water cleanup standards are MCLs, both onsite and offsite, and Livermore Site cleanup efforts are designed to achieve these goals. The point of compliance is the impacted ground water body, both onsite and

offsite. The cleanup is projected to be complete in 2077, with a remaining cost (after FY 2003) of \$692M.

3. **Risk-Based End State** – The end state the site would be in based on planned future site use that is protective of human health and the environment for that site use. The timeframe for implementing the remedial actions required to achieve this end state is the current EM mission completion date for the Livermore Site (FY 2006). Under a Risk-Based End State approach, the cleanup strategy would be modified to: (1) clean up offsite ground water to MCLs, and (2) prevent further offsite migration of contaminants at concentrations exceeding MCLs. Ground water extraction would be limited to ensuring that MCLs are achieved and maintained offsite. Modeling to predict the residual concentration and distribution of contamination under this scenario has not yet been performed. The Risk-Based End State may require additional extraction wells and treatment facilities at the site boundary if cleanup in the interior of the site is reduced. The point of compliance would be the site boundary. No cleanup time or cost estimates have been generated for this scenario.

The only significant strategic difference between the Current Cleanup Baseline End State and the Risk-Based End State is the point of compliance for contaminated ground water. The two end states are identical in terms of exposure of offsite receptors to contaminants from the Livermore Site, and address risk to these receptors equivalently. However, onsite cleanup of ground water under the Current Cleanup Baseline End State is intended to restore and protect ground water as a potential future resource, rather than to specifically mitigate risk. The Risk-Based End State presents a scenario based only on risk, but does not remediate onsite ground water to levels protective of ground water as a potential future resource.

For each exposure pathway where unacceptable carcinogenic risk or noncarcinogenic hazard was identified in the baseline risk assessment, barriers to exposure are described for both the Current Cleanup Baseline End State and the Risk-Based End State. For each exposure barrier: (1) residual risk (risk remaining at the End State, if available) and, (2) a failure analysis are presented.

### **Variances**

The variances between the Current Cleanup Baseline End State and the Risk-Based End State are the differences between current cleanup plans and/or regulatory agreements and the Risk-Based End State Vision. For the Livermore Site, a variance has been identified based on input from the regulatory agencies, local government, and the community.

The Current Cleanup Baseline End State assumes that all ground water contaminated by Livermore Site activities must ultimately be remediated in a manner consistent with current environmental regulations and existing compliance agreements, both onsite and offsite. The impacted ground water body is assumed to be the point of compliance. The Risk-Based End State Vision assumes that the site boundary would be the point of compliance for contaminants in ground water. The Risk-Based End State Vision is not consistent with Federal and State environmental regulations and existing compliance agreements in terms of onsite cleanup of ground water.

This issue is discussed in more detail in the Variance Report attached to this Risk-Based End State Vision document.

## 1. Introduction

This Risk-Based End State (RBES) Vision for the Lawrence Livermore National Laboratory (LLNL) Livermore Site was prepared in response to one of the Corporate Projects (“A Cleanup Program Driven by Risk-Based End States”) established by the U.S. Department of Energy (DOE) Office of Environmental Management (EM) in response to the EM Top-to-Bottom Review completed in 2002. DOE sites are directed to create Risk-Based End State Visions for submission to the Assistant Secretary for Environmental Management. This Livermore Site Risk-Based End State Vision was prepared according to the September 2003 *Guidance for Developing a Risk-Based End State Vision*, the December 2003 *Clarification Addendum to Guidance for Developing a Site-Specific Risk-Based End State Vision*, and to comply with DOE Policy 455.1, *Use of Risk-Based End State*. One of the primary goals of the Risk-Based End State Corporate Project is to transform the varying applications and/or versions of essential management tools (e.g., land-use maps, conceptual site models) developed at individual DOE sites into a single unified approach.

The Risk-Based End State Vision focuses on ensuring that the U.S. Department of Energy (DOE) cleanup strategy is driven by risk to human and ecological receptors. DOE recognizes that the End State Vision may not agree with existing site compliance agreements or regulations. The Risk-Based End State approach attempts to gain a common acceptance of the site-wide post-remediation future. After Risk-Based End States are developed, sites will re-evaluate their cleanup activities and strategic approaches to determine if it is appropriate to change site baseline documents and renegotiate agreements with the regulatory agencies. If DOE ultimately decides to seek changes to the current compliance agreements, decisions, or statutory/regulatory requirements, those changes will be made in accordance with applicable requirements and procedures.

Future land use conditions described in this document consider a 20-year timeframe. This timeframe is typically used by governmental organizations to evaluate growth changes in terms of population and service needs. This provides a documented foundation for land use, exposure scenarios, and other aspects of risk assessment in this Risk-Based End State Vision document. The 20-year timeframe does not apply in any way to cleanup strategies and should not be inferred to mean that DOE anticipates that cleanup will be discontinued in 20 years (or at any arbitrary time in the future). This Risk-Based End State Vision is consistent with the National Nuclear Safety Administration (NNSA) Ten Year Comprehensive Site Plan.

The scope of this Risk-Based End State Vision for the Livermore Site includes evaluating strategies to perform cleanup of contaminants released during past operations. Waste management and facility decontamination/decommissioning are not included because these activities are not likely to impact future land use or cause risk to humans or ecological receptors.

The primary sources of information used to prepare this document include:

- Baseline Public Health Assessment for CERCLA Investigations at the LLNL Livermore Site (Layton et al., 1990).
- CERCLA Remedial Investigations Report for the LLNL Livermore Site (Thorpe et al., 1990).
- CERCLA Feasibility Study for the LLNL Livermore Site (Isherwood et al., 1990).

- Proposed Remedial Action Plan for the LLNL Livermore Site (Dresen et al., 1991).
- Record of Decision for the LLNL Livermore Site (U.S. DOE, 1992).
- Remedial Action Implementation Plan for the LLNL Livermore Site (Dresen et al., 1993).
- Contingency Plan for the LLNL Livermore Site (McKereghan et al., 1996).
- Second Five-Year Review for the LLNL Livermore Site (Berg et al., 2002).
- Draft Site Wide Environmental Impact Statement for the Continued Operation of LLNL and Support of Stockpile Stewardship and Management Program Environmental Impact Statement (DOE, 2004).
- LLNL Livermore Site Baseline Work Plan.
- Alameda County Planning Department.
- City of Livermore.

Full references are provided in Section 5.

## **1.1. Organization**

This document presents a series of standardized maps that show the Current State and Risk-Based End State for the physical and surface interface; human and ecological land use; land ownership; demographics; and hazards at regional, site-specific, and site-level scales. Chapter 2 of this document presents regional-scale maps of the physical and surface interface, and human and ecological land use. Chapter 3 presents site-specific maps that show the physical and surface interface, human and ecological land use, legal ownership and demographics. Chapter 4 presents Conceptual Site Models and Hazard Maps. The text discusses features not apparent on the maps or that supplement the maps and differences between the Current State and Risk-Based End State maps and Conceptual Site Models.

## **1.2. Livermore Site Mission**

The primary mission of the Livermore Site is to ensure that the nation's nuclear weapons remain safe, secure, and reliable and to prevent the spread and use of nuclear weapons worldwide. Livermore Site programs include advanced defense technologies, energy, environmental sciences, biosciences, and basic science applied to the enhancement of national security. The Livermore Site is a contributor to the Stockpile Stewardship and Homeland Security programs. Statements from Congressional representatives and the Administration regarding the importance of the National Laboratories to the nation's continued scientific and defense interests indicate that the Livermore Site will continue to exist and serve this mission for the foreseeable future.

## **1.3. Status of the Livermore Site Cleanup Program**

During past Livermore Site operations, volatile organic compounds (VOCs), primarily trichloroethylene (TCE) and perchloroethylene (PCE), tritium, fuel hydrocarbons, and metals were released to the environment. Initial hazardous materials releases occurred in the mid- to late-1940s when the site was the Livermore Naval Air Station. There is also evidence that

localized spills, unlined landfills, and leaking tanks and impoundments contributed contaminants to soil and ground water in the post-Navy era. VOCs and metals are present in ground water in concentrations above drinking water standards. It is currently estimated that about 3 billion gallons of ground water to a depth of about 200 feet is contaminated.

Environmental restoration activities at the Livermore Site are regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The site was added to the CERCLA National Priorities List in 1987. The U.S. Environmental Protection Agency (EPA), the California Department of Toxic Substances Control (DTSC), and the California Regional Water Quality Control Board (RWQCB) provide regulatory oversight. DOE is the lead agency for environmental restoration at the Livermore Site.

A Record of Decision (ROD) for the Livermore Site was signed in 1992 (U.S. DOE, 1992). The cleanup standards established in the ROD specify that ground water will be remediated to Maximum Contaminant Levels (MCLs) both onsite and offsite. Four Explanations of Significant Differences have been prepared to modify the remedies selected in the ROD. Two Five-Year Reviews on the progress of the cleanup have been prepared since the ROD was signed.

The selected remedies for the Livermore Site cleanup consist of extracting and treating contaminated ground water and soil vapor. The Livermore Site cleanup has been expedited by implementing an Engineered Plume Collapse strategy, “smart” pump and treat, contaminant source isolation, portable treatment unit technology, and innovative remediation technologies such as catalytic reductive dehalogenation. Significant progress has been made in reducing the extent and concentrations of the ground water VOC plume that extended offsite to the west of the Livermore Site, and in controlling and reducing the concentrations and mass of onsite VOCs. Several waste pits have been excavated, but there is no impact to ground water from these pits. The two Five-Year Reviews have concluded that the existing remediation network continues to function as intended and is protecting human health and the environment.

As specified in the ROD, the objective of the Livermore Site cleanup is to achieve a rapid, efficient, and cost-effective remediation within budgetary constraints and in compliance with regulatory requirements. The remediation strategy for the Livermore Site employs a prioritized approach with an emphasis on risk reduction. The overall cleanup objectives are to protect human health and the environment, control and prevent further offsite plume migration, and to clean up and restore the beneficial use of ground water. In agreement with the regulatory agencies and the neighboring community, the following priorities have been established for the Livermore Site in the 1994 Consensus Statement:

- Control the western ground water VOC plume boundary, prevent further offsite plume migration, and clean up offsite plumes. Prevent contamination of water-supply wells and associated risk to human health and loss of beneficial uses of ground water.
- Control the southern ground water plume boundary, prevent further offsite plume migration, and clean up offsite plumes.
- Control and clean up internal contaminant sources.

Milestones for cleanup the Livermore Site are established in conjunction with the overseeing regulatory agencies with input from the local community, and are specified in an attachment to the Livermore Site Remedial Action Implementation Plan (Dresen et al., 1993).

## **2. Risk-Based End State Vision: Regional Context**

### **2.1. Physical and Surface Interface**

Regional-scale Current State and Risk-Based End State physical and surface interface maps are presented in Figure 2.1a,b. The Livermore Site is located immediately east of the City of Livermore and is accessible by major freeways and roads. The 821-acre site slopes very gently to the northwest and is enclosed by fencing patrolled by LLNL security staff. Two active fault zones, the Greenville Fault Zone to the east and the Las Positas Fault Zone to the south, are located within one mile of the Livermore Site. Wind turbines for generating electricity are located in the hills east and northeast of the Livermore Site.

There are no differences between the Current State and Risk-Based End State.

### **2.2. Human and Ecological Land Use**

Figure 2.2a,b shows the regional human and ecological land use for the Current State and the Risk-Based End State. West of the Livermore Site is a combination of residential and commercial land associated with the City of Livermore, with some agricultural land interspersed. The map indicates agricultural land use north of the site, but much of this area is being developed with light industrial and commercial buildings. Non-agricultural vegetated grasslands (primarily private cattle ranches) are present to the east and southeast. Sandia National Laboratories (Livermore) is located immediately south of the site, with agricultural and non-agricultural lands further south.

No critical ecological habitats currently exist at the Livermore Site. The site was designated as critical habitat for the threatened California red-legged frog until 2002. Areas containing the elements of a wetland are present at the Livermore Site, including two arroyos, one artificial lake, and several drainage ditches. Although these areas have not been officially designated as wetlands, LLNL manages them as such. The white-tailed kite, a California State fully-protected raptor, also occupies the Livermore Site during nesting periods. LLNL biologists use Best Management Practices to control unnecessary activities near the nesting sites to enhance the probability of successful hatches.

There are no differences between the Current State and Risk-Based End State.

### **3. Site-Specific Risk-Based End State Description**

#### **3.1. Physical and Surface Interface**

Site-specific Current State and Risk-Based End State physical and surface interface is shown on Figure 3.1a,b. Two intermittent streams, Arroyo Seco and Arroyo Las Positas, are present in the vicinity of the Livermore Site. Northwest-flowing Arroyo Seco traverses the southwest corner of the site. This arroyo typically contains water only during and after winter storms, but currently three facilities discharge treated ground water into the Arroyo and causes very localized flow. West-flowing Arroyo Las Positas approaches the site from the east where it has been diverted to flow along the eastern and northern site boundaries. Arroyo Las Positas flows perennially along the northern site boundary due to surface discharges of treated ground water from the Livermore Site. The South Bay Aqueduct is present southeast and east of the site, and the Patterson filtration reservoir is located about 0.5 miles east-northeast of the site. Two railroad tracks are present within one mile of the northern site boundary.

Figure 3.1a,b shows the extent of ground water and soil contamination and the locations of the current Livermore Site treatment facilities. The nearest commercial or municipal potable water supply wells are located about 1.5 miles west of the western leading edge of the ground water VOC plume. Other wells used to supply irrigation and drinking water to ranches and homes are located immediately southeast and west-southwest of the site. In addition, wells supplying irrigation water for the Wente vineyards are located about one half a mile west-southwest of the Livermore Site.

There are no differences between the Current State and Risk-Based End State.

#### **3.2. Human and Ecological Land Use**

Figures 3.2a and 3.2b, respectively, show the site-specific Current State and Risk-Based End State human and ecological land use within and adjacent to the Livermore Site. Onsite land uses include offices, laboratory buildings, support facilities, roadways, parking areas, and landscaping. A security buffer zone 400 to 500 feet wide is present west and north of the site. Figure 3.2a shows that City of Livermore residential land consisting of single-family homes adjoins the site to the west and southwest. An athletic field park is located immediately northwest of the site. Figure 3.2a also shows commercial light industrial land use north and northwest of the site. The land northeast and southeast of the Livermore Site is predominantly grass-covered ranch land that is used largely for cattle grazing. A small oil field, the Livermore Oil Field, is located just south of Patterson Pass Road about one half mile east of the Livermore Site. Relatively small parcels of commercial land are present southwest and east of the site, including a Western Area Power Administration substation at the southeast corner of Greenville and Patterson Pass Roads. Small residential parcels exist east of the site.

East Avenue, which forms the southern boundary of the Livermore Site, was closed to unrestricted travel in 2003 for security purposes. This closure is not anticipated to impact future land use.

Sandia National Laboratories (Livermore) is located immediately south of the Livermore Site. The site use is currently industrial, but future agricultural use is planned for portions of the site, as shown on Figure 3.2b.

There are no other differences between the Current State and Risk-Based End State maps.

### **3.3. Site Context Legal Ownership**

Current State and Risk-Based End State ownership is shown on Figure 3.3a,b. The Livermore Site and the Sandia National Laboratories property to the south are owned by the Federal government (U.S. Department of Energy). All the land in the immediate vicinity to the north, east, and west of the Livermore Site is privately owned.

There are no differences between the Current State and Risk-Based End State.

### **3.4. Site Context Demographics**

Figure 3.4a,b shows the population density in the Livermore Site vicinity for the Current State and Risk-Based End State. Higher population densities (500 – 5,000 people per square mile) near the Livermore Site are limited to the residential areas immediately to the west. The area north, east, and south of the site is characterized by low population density, less than 150 people per square mile. Because there are no available population density projections, there are no differences between the Current State and Risk-Based End State.

## 4. Hazard Specific Discussion

Initial hazardous materials releases occurred at the Livermore Site in the mid- to late-1940s when the site was the Livermore Naval Air Station. There is also evidence that localized spills, unlined landfills, and leaking tanks and impoundments released contaminants to the ground water and unsaturated sediments in the post-Navy era.

For the purposes of this document, the Livermore Site is defined as a single Site-wide Hazard Area due to the similarities in:

- **Release Mechanism** – The releases are predominantly point source, resulting from discharges to the ground surface or shallow soil.
- **Primary and Secondary Sources** – The environmental media affected are ambient air, soil, sediment, and ground water.
- **Release, Transport, and Exposure Mechanisms** – These factors are similar for all release areas at the Livermore Site, and include subsurface flow and transport, and ingestion, inhalation, and dermal exposure pathways.
- **Extent of Contamination** – Contamination from release areas at the Livermore Site is generally contained within the site boundary. The extent of offsite contamination (south and southwest of the site) has been reduced by aggressive remedial actions.
- **Temporary Barriers or Controls** – All release areas at the Livermore Site share similar controls, such as measures to restrict access to contaminated areas.
- **Remediation, Mitigation, and Other Interventions** – Remediation is underway at most of the release areas at the Livermore Site. Remedial technologies include soil vapor and/or ground water extraction and treatment.
- **Future Land Use** – All release areas at the Livermore Site are located within the boundary of the site. It is assumed that DOE will maintain control of the site for the foreseeable future.

Three exposure scenarios are described and compared:

1. **Current State** – Conditions at the Livermore Site in 2003. The DOE Office of Environmental Management (EM) is now responsible for cleanup activities. After EM mission completion (anticipated to occur at the end of Fiscal Year [FY] 2006) oversight of cleanup will be transferred to the National Nuclear Safety Administration (NNSA).
2. **Current Cleanup Baseline End State** – The end state the site will be in after implementing the existing cleanup strategy. This is based on the requirements in current baseline work plan documents, compliance agreements, including the 1992 Record of Decision for the Livermore Site, and environmental regulations. The timeframe for implementing the remedial actions required to achieve this end state is the current EM mission completion date for the Livermore Site (FY 2006). At the Livermore Site, these remaining remedial actions include installing several additional ground water and soil vapor extraction and treatment facilities. However, cleanup activities will continue after EM mission completion (e.g., long-term ground water extraction). At the Livermore Site, compliance documents currently specify that ground water cleanup standards are MCLs,

both onsite and offsite, and Livermore Site cleanup efforts are designed to achieve these goals. The point of compliance is the impacted ground water body, both onsite and offsite. The cleanup is projected to be complete in 2077, with a remaining cost (after FY 2003) of \$692M.

3. **Risk-Based End State** – The end state the site would be in based on planned future site use that is protective of human health and the environment for that site use. The timeframe for implementing the remedial actions required to achieve this end state is the current EM mission completion date for the Livermore Site (FY 2006). Under a Risk-Based End State approach, the cleanup strategy would be modified to: (1) clean up offsite ground water to MCLs, and (2) prevent further offsite migration of contaminants at concentrations exceeding MCLs. Ground water extraction would be limited to ensuring that MCLs are achieved and maintained offsite. Modeling to predict the residual concentration and distribution of contamination under this scenario has not yet been performed. The Risk-Based End State may require additional extraction wells and treatment facilities at the site boundary if cleanup in the interior of the site is reduced. The point of compliance would be the site boundary. No cleanup time or cost estimates have been generated for this scenario.

The only significant strategic difference between the Current Cleanup Baseline End State and the Risk-Based End State is the point of compliance for contaminated ground water. The two end states are identical in terms of exposure of offsite receptors to contaminants from the Livermore Site, and address risk to these receptors equivalently. However, onsite cleanup of ground water under the Current Cleanup Baseline End State is intended to restore and protect ground water as a potential future resource, rather than to specifically mitigate risk. The Risk-Based End State presents a scenario based only on risk, but does not remediate onsite ground water to levels protective of ground water as a potential future resource.

The Site-wide Hazard Maps for the Current State and the Risk-Based End State are presented as Figures 4.0a and 4.0b, respectively. The Site-wide Conceptual Site Model for the Current State and Risk-Based End State is presented as Figure 4.0a2,b2. Because the only significant difference between the Current Cleanup Baseline End State and the Risk-Based End State is the point of compliance for ground water, Conceptual Site Model depicts both end states. On the Conceptual Site Model diagram, active pathways are shown as solid lines, blocked pathways are shown as dashed lines, and incomplete pathways are shown as dotted lines. Barriers are shown as heavy vertical or horizontal lines across the exposure pathway they break. The barriers are not equal in their ability to block an exposure pathway. Multiple barriers may be required to assure sustainable protection for current and future receptors.

#### 4.1. Hazard Area Description

During past Livermore Site operations, VOCs, tritium, fuel hydrocarbons, and metals were released to the environment. Initial hazardous materials releases occurred in the mid- to late-1940s when the site was the Livermore Naval Air Station. There is also evidence that localized spills, unlined landfills, and leaking tanks and impoundments contributed contaminants to soil and ground water in the post-Navy era.

Contaminants in ground water at the Livermore Site include:

- 1,1-Dichloroethene (1,1-DCE).

- Benzene.
- Carbon tetrachloride.
- Chloroform.
- Chromium.
- Ethylbenzene.
- Hexavalent chromium.
- Tetrachloroethene (PCE).
- Toluene.
- Total xylene isomers.
- Trichloroethene (TCE).
- Tritium.

The maximum current concentrations of contaminants in ground water and the respective cleanup standards (MCLs) are presented in Table□.

The selected remedies for the Livermore Site cleanup consist of extracting and treating contaminated ground water and soil vapor. The Livermore Site cleanup has been expedited by implementing Engineered Plume Collapse, “smart” pump and treat, contaminant source isolation, portable treatment unit technology and innovative remediation technologies such as catalytic reductive dehalogenation. Significant progress has been made in reducing the extent and concentrations of the ground water VOC plume that extended offsite to the west of the Livermore Site, and in controlling and reducing the concentrations and mass of onsite VOCs. The two Five-Year Reviews have concluded that the existing remediation network continues to function as intended and is protecting human health and the environment.

Cleanup activities thus far have established hydraulic control of the western and southern margins of the ground water contaminant plumes and are preventing further offsite migration. In fact, the extent of ground water contamination west of the Livermore Site has been significantly reduced by ground water extraction and treatment over the last 14 years. Numerous soil vapor and/or ground water extraction and treatment systems are currently operating at the Livermore Site.

#### **4.1.1. Baseline Human Health Risk Assessment Summary**

As part of the Remedial Investigation report (Thorpe et al., 1990), the Baseline Public Health Assessment (Layton et al., 1990) was conducted to estimate the potential future health risks if contaminants in ground water and sediments originating from the Livermore Site were not remediated. In addition, a risk assessment was conducted as part of the Feasibility Study (Isherwood et al., 1990) to estimate the potential public health risks if the concentrations of volatile organic compounds (VOCs) in ground water were reduced to their respective maximum contaminant levels (MCLs). These and other assessments of potential risks are summarized in the Proposed Remedial Action Plan (Dresen et al., 1991) and the Record of Decision (U.S. DOE, 1992). Details of the risk assessments are contained in the Remedial Investigation and Feasibility Study and assessment of the risks were re-examined in the Second Five Year Review (Berg et al., 2002). In addition, studies were conducted in 1991 to evaluate the inhalation risk of

VOCs to building occupants. The results reaffirmed that volatilization of VOCs from the unsaturated zone do not present a health risk at the Livermore Site (Berg et al., 2002).

#### **4.1.1.1. Media of Concern**

The primary medium through which public exposure to Livermore Site contaminants may occur is ground water. Air is also a medium of concern for contaminants that may volatilize from contaminated soil or ground water. The public is not directly exposed to contaminated soils because no offsite surface soil contains significant concentrations of contaminants originating from the Livermore Site. Contaminated onsite surface soil was evaluated as a potential medium of concern. However, a screening analysis of the risks resulting from potential onsite exposure to contaminated soil has shown these risks are insignificant (Layton et al., 1990). Therefore, surface soil is not a medium of concern for the Livermore Site.

In 1991, the Livermore Site evaluated the inhalation risk of VOCs to building occupants. The results indicated that volatilization of VOCs from the unsaturated zone do not present a health risk at the Livermore Site (Berg et al., 2002).

#### **4.1.1.2. Contaminants of Concern**

A screening analysis was conducted to determine which substances and exposure pathways are potentially important from the perspective of potential adverse health effects. A statistical analysis of thousands of water and soil samples estimated the relative abundance of particular contaminants in the study area (Layton et al., 1990). TCE, PCE, and chloroform account for an estimated 91% of the total amount of VOCs dissolved in the Livermore Site area ground water. Of the remaining VOCs, the most hazardous are carbon tetrachloride and 1,1-DCE, which were used to represent the potential adverse effects of the remaining 9% of the VOCs. Nearly 60% of the mass of the remaining 9% of VOCs is 1,1-DCE. These compounds were used to estimate the public health risks resulting from the offsite migration and domestic use of contaminated ground water. According to the U.S. EPA, PCE, TCE, chloroform, and carbon tetrachloride are classified as B2 carcinogens, which are described as “probable human carcinogens indicated by sufficient evidence in animals and inadequate or no evidence in humans.” 1,1-DCE is classified as a Class C carcinogen by the U.S. EPA (possible human carcinogen).

Other contaminants in soil and ground water include benzene at the Gasoline Spill Area, tritium, and inorganic substances, such as chromium, lead, nitrate, sulfate, and manganese. A screening analysis of the transport and fate of benzene indicates that benzene or other gasoline-related contaminants (toluene, xylene isomers, and ethylbenzene) are not likely to reach detectable concentrations west of the Livermore Site. Similarly, tritium continues to undergo radioactive decay with a 12.3-year half-life such that by the time ground water containing elevated levels of tritium would migrate to the western Livermore Site boundary in the absence of remediation, concentrations would be within background levels.

#### **4.1.1.3. Exposure Pathways**

The only potential exposure pathway for present and future offsite populations is use of contaminated well water. For domestic water uses, the potential exposure pathways are ingestion of drinking water, inhalation of volatile substances, and entry through the skin. For irrigation uses, the potential exposure pathways are inhalation of volatilized chemicals from sprinklers, and ingestion of foods from crops or home gardens irrigated with water containing the

chemicals of concern. Exposure from contact with surface water runoff or sediment in local arroyos that receive drainage waters from the Livermore Site is not a pathway of concern, because no chemicals of concern have been detected in downstream drainage channels nor does ground water discharge to streams near the Livermore Site. The most important offsite exposure pathways with regard to health risk are those that result from domestic well water use from offsite wells (Thorpe et al., 1990).

#### ***4.1.1.4. Potentially Exposed Population***

There are no significant onsite exposure pathways for Livermore Site contaminants. The only potentially exposed offsite population consists of residents who use ground water that has migrated from the Livermore Site. In the assessments of risk for the Livermore Site, a future onsite residential-use scenario was not considered because it is unlikely that transfer of ownership of the site from DOE would occur in the foreseeable future. No change in ownership of the Livermore Site or any portion thereof, or notice pursuant to Section 120 of CERCLA, will relieve DOE of its obligation to clean up contamination resulting from DOE activities, or any future contamination resulting from DOE activities at the Livermore Site. In addition, no change of ownership of the site or any portion thereof can be performed by DOE without provision for continued maintenance of any containment system, treatment system, monitoring system, or other response action(s) installed or implemented under terms of the LLNL Federal Facility Agreement. Recreational use of the site and intruder/trespasser exposure scenarios are not applicable to the Livermore Site and were not evaluated in the baseline risk assessment:

#### ***4.1.1.5. Exposure Point Concentration Estimates***

To assess the potential future health risks of the known contaminants in ground water, the movement of VOCs from their current distribution was simulated with a model. A semianalytical model of contaminant transport and fate in ground water was used that considers advection, dispersion, retardation, and degradation. To address uncertainty inherent in all contaminant migration calculations, two scenarios were investigated, one called "best-estimate" and the other "health-conservative." The health-conservative scenario uses parameter values and assumptions that yield exposures that are very unlikely to be exceeded. U.S. EPA prefers using the most conservative of the health-conservative scenarios as their estimate of the potential health risk from the Livermore Site. The best-estimate simulations use parameter values that are considered to be the most likely or the most representative, based on existing knowledge of the Livermore Site ground water system and contaminant properties. Best-estimate simulation assumes no human exposure to the ground water until it reaches the currently used municipal supply wells in downtown Livermore because no private wells are currently contaminated and administrative control limits the potential for domestic well installation into a contaminated zone. The administrative control consists of notification by Zone 7, the local water agency, that a proposed new well is in or near the contaminant plume.

#### ***4.1.1.6. Exposure Frequency and Duration***

The exposure period for the offsite public for any exposure pathway of concern was assumed to be a 70-year lifetime. For offsite exposures to contaminated ground water, the fate and transport model was used to calculate maximum 70-year average concentrations in ground water at existing and potential offsite wells. It was assumed that the exposed population uses ground

water as its sole source of domestic water for this continuous 70-year period. These and other assumptions were used to estimate the total daily uptake of each chemical of concern in milligrams of chemical per kilogram body mass per day (mg/kg-day).

#### **4.1.1.7. Carcinogenic Risks**

Under the best-estimate exposure scenario, the greatest incremental cancer risk is seven in ten million ( $7 \times 10^{-7}$ ), which is associated with a well 2 miles west of the Livermore Site that is in the path of the plume containing the highest concentrations of 1,1-DCE (Layton et al., 1990). Under the health-conservative exposure scenario, the incremental cancer risks are on the order of one in one thousand ( $10^{-3}$ ) to one in one million ( $10^{-6}$ ) for all wells. The highest predicted risk, two in one thousand ( $2 \times 10^{-3}$ ), is for a hypothetical well about 250 feet west of the Livermore Site. However, no such wells have been constructed to date or are planned for installation prior to cleanup. The most conservative of the health-conservative scenarios (i.e.,  $2 \times 10^{-3}$  incremental risk) is the scenario prescribed by EPA for the Livermore Site.

#### **4.1.1.8. Potential for Non-carcinogenic Effects**

Potential non-carcinogenic effects of a single contaminant in a single medium is expressed as the hazard quotient (or the ratio of the estimated intake derived from the contaminant concentration in a given medium to the contaminant's reference dose). By adding the hazard quotients for all contaminants within a medium or across all media to which a given population may be reasonably exposed, the hazard index can be estimated. If only one compound is involved, then the hazard quotient is equivalent to the hazard index. If the hazard index value is greater than 1.0, exposure could result in adverse health effects. The hazard index provides a useful reference for gauging the potential significance of multiple contaminant exposures within a single medium or across media.

Under the best-estimate exposure scenario, the greatest hazard quotient is  $1.4 \times 10^{-3}$ , which is for a hypothetical well 2 miles west of the Livermore Site in the path of the plume containing the highest concentrations of carbon tetrachloride. Under the health-conservative exposure scenario the hazard quotients are on the order of  $10^{-2}$  to  $10^{-1}$  for all wells. The highest predicted hazard quotient (0.8) is for a hypothetical well that is 250 feet west of the Livermore Site.

#### **4.1.1.9. Combined Carcinogenic Risks and Hazard Indices**

Under the health-conservative no-remediation scenario, the maximum additional cancer risk is two in one thousand ( $2 \times 10^{-3}$ ) for a lifetime exposure to contaminants in water from a potential monitor well drilled 250 feet west of the Livermore Site. The hazard index calculated for this scenario is 1. Because no drinking water wells are likely to be drilled in the area 250 feet west of the Livermore Site, the risk was also calculated based on a lifetime exposure to well water derived from downtown Livermore using the health-conservative assumptions. This unlikely scenario results in a maximum additional cancer risk of one in one thousand ( $1 \times 10^{-3}$ ) and a hazard index of 1. The hazard index of 1 for the health-conservative scenario indicates that there is some potential for non-carcinogenic health effects if the very conservative assumptions of the health-conservative scenario were ever realized, and if there was an additive effect of all the individual compounds. The health-conservative risks exceed the EPA one in ten thousand to one in ten million ( $1 \times 10^{-4}$  to  $1 \times 10^{-7}$ ) acceptable risk range for Superfund sites.

#### **4.1.2. Baseline Ecological Risk Assessment Summary**

Currently, there is no potential risk of ecological impacts related to environmental exposure to ground water because no ground water containing contaminants is present at the surface, either onsite or offsite. No perennial streams exist at or near the site and no streams receive flow from ground water. No critical habitats are affected by the ground water and soil contamination. No endangered species or habitats of endangered species are affected by the site contaminants, as described in the FS (Isherwood et al., 1990).

#### **4.2. Primary and Secondary Sources**

Primary sources are locations where contaminants were produced, deposited, released, or disposed. The primary sources at the Livermore Site include:

- Surface spills.
- Piping and underground storage tank leaks.
- Disposal pits.
- Landfills.
- Evaporation ponds.
- Storm drains.

Secondary sources are environmental media to which contaminants have migrated. Secondary sources include:

- Vadose (unsaturated) zone soil and sediment.
- Ground water.

It is assumed that primary and secondary contaminant sources under the Current Cleanup Baseline End State and Risk-Based End State exposure scenarios are equivalent.

#### **4.3. Release, Transport, and Exposure Mechanisms**

The contaminant release, transport, and exposure mechanisms under the Current State, Current Baseline End State, and Risk-Based End State exposure scenarios are described below. Receptors are also identified.

##### **4.3.1. Release Mechanisms**

Release mechanisms are the manner in which contaminants migrate from a primary source to an environmental medium (secondary source). The only release mechanism at the Livermore Site is leakage or discharge of contaminants to surface soil or the vadose zone. Volatilization of contaminants directly from the released contaminant is not applicable because contaminants have already migrated into environmental media and no active sources remain. It is assumed that the release mechanisms under the Current Cleanup Baseline End State and Risk-Based End State exposure scenarios are equivalent.

#### 4.3.2. Transport Mechanisms

Transport mechanisms describe the migration of contaminants between environmental media. The only potential transport mechanism is infiltration of contaminants from the vadose zone to ground water.

The following transport mechanisms are not applicable:

- **Volatilization of contaminants from surface soil or the vadose zone to ambient indoor and outdoor air** – There are no areas where unacceptable risk or hazard has been identified for this exposure pathway.
- **Resuspension of contaminated soil particles to outdoor ambient air** – There are no areas where unacceptable risk or hazard has been identified for this exposure pathway.
- **Outflow from ground water to surface water** – There is no outflow of ground water to surface water in the vicinity of the Livermore Site.
- **Transport of contaminants by runoff from surface soil or the vadose zone to surface water** – There are no areas where unacceptable risk or hazard has been identified for this exposure pathway.
- **Transport of contaminants by recharge from surface water to ground water** – There are no contaminated surface water bodies at the Livermore Site.

It is assumed that transport mechanisms under the Current Cleanup Baseline End State and Risk-Based End State exposure scenarios are equivalent to those described in the Current State exposure scenario.

#### 4.3.3. Exposure Mechanisms and Receptors

Exposure mechanisms describe how contaminants move from contaminated environmental media to human or ecological receptors. Receptors are human or ecological species that are potentially exposed to, or adversely affected by, contaminants. In the baseline risk assessment, all potential exposure mechanisms and receptors were considered. Exposure mechanisms and receptors for which no unacceptable risk or hazard was identified in the baseline risk assessment are not discussed further. At the Livermore Site, unacceptable risk or hazard was identified for the following exposure mechanism and receptor:

- **Ingestion of contaminated ground water by offsite residential receptors** - Unacceptable risks were identified at hypothetical water-supply wells that could be installed at the site boundary. Under the best-estimate exposure scenario, the greatest incremental cancer risk is seven in ten million ( $7 \times 10^{-7}$ ), which is associated with a well 2 miles west of the Livermore Site that is in the path of the plume containing the highest concentrations of 1,1-DCE (Layton et al., 1990). Under the health-conservative exposure scenario, the incremental cancer risks are on the order of one in one thousand ( $10^{-3}$ ) to one in one million ( $10^{-6}$ ) for all wells. The highest predicted risk, two in one thousand ( $2 \times 10^{-3}$ ), is for a hypothetical well about 250 feet west of the Livermore Site. However, no such wells have been constructed to date or are planned for installation prior to cleanup. The most conservative of the health-conservative scenarios (i.e.,  $2 \times 10^{-3}$  incremental risk) is the scenario prescribed by U.S. EPA for the Livermore Site. Under the best-estimate exposure scenario, the greatest hazard quotient is  $1.4 \times 10^{-3}$ , which is for a hypothetical well 2 miles west of the Livermore Site in the path of the

plume containing the highest concentrations of carbon tetrachloride. Under the health-conservative exposure scenario the hazard quotients are on the order of  $10^{-2}$  to  $10^{-1}$  for all wells. The highest predicted hazard quotient (0.8) is for a hypothetical well that is 250 feet west of the Livermore Site.

Under the health-conservative no-remediation scenario, the maximum additional cancer risk is two in one thousand ( $2 \times 10^{-3}$ ) for a lifetime exposure to contaminants in water from a potential monitor well drilled 250 feet west of the Livermore Site. The hazard index calculated for this scenario is 1. Because no drinking water wells are likely to be drilled in the area 250 feet west of the Livermore Site, the risk was also calculated based on a lifetime exposure to well water derived from downtown Livermore using the health-conservative assumptions. This unlikely scenario results in a maximum additional cancer risk of one in one thousand ( $1 \times 10^{-3}$ ) and a hazard index of 1. The hazard index of 1 for the health-conservative scenario indicates that there is some potential for non-carcinogenic health effects if the very conservative assumptions of the health-conservative scenario were ever realized, and if there was an additive effect of all the individual compounds. The health-conservative risks exceed the EPA one in ten thousand to one in ten million ( $1 \times 10^{-4}$  to  $1 \times 10^{-7}$ ) acceptable risk range for Superfund sites.

It is assumed that exposure mechanisms and receptors under the Current Cleanup Baseline and Risk-Based End State exposure scenarios are equivalent.

#### **4.4. Temporary Barriers or Controls**

Temporary controls have been implemented at the Livermore Site, including measures to prevent unacceptable risk to onsite workers engaged in activities in which they may be exposed to contaminated soil, such as during construction. These controls are implemented through existing worker health and safety plans. It is assumed that the temporary barriers and controls that would be implemented under the Current Cleanup Baseline and Risk-Based End State exposure scenarios are equivalent.

#### **4.5. Remediation, Mitigation, and Other Intervention**

The following sections describe the exposure barriers that would be implemented under the Current Cleanup Baseline End State and the Risk-Based End State scenarios. These barriers prevent or mitigate human or ecological exposure to contaminants. For each exposure barrier, the residual risk that would remain after remediation is complete is presented, and uncertainties or failure modes that could result in exposure are described. However, the Contingency Plan for the Livermore Site (McKereghan et al., 1996) identifies situations where the cleanup may not proceed as anticipated, and includes response actions to address these occurrences, should they arise.

##### **4.5.1. Exposure Barrier 1 – Soil Vapor Extraction**

Soil vapor extraction has been implemented at the Livermore Site to protect ground water from potential or further degradation due to downward migration of contaminants from the vadose zone. Protection of ground water leads to mitigation of risk to onsite and offsite receptors through a ground water exposure pathway.

Under the Current Cleanup Baseline End State scenario, onsite soil vapor extraction would be continued until vadose zone concentrations protective of onsite and offsite ground water are achieved, although there are no established vadose zone cleanup standards for the Livermore Site.

Under the Risk-Based End State scenario, onsite soil vapor extraction would be continued only until concentrations protective of offsite ground water are achieved. The time or cost remaining to achieve this objective has not been determined. There would be no risk to all identified receptors if land use remains as anticipated.

Since there is no identified offsite vadose zone contamination, there will be no residual risk to all identified receptors if land use remains as anticipated under both the Current Cleanup Baseline End State and the Risk-Based End State.

Uncertainties or failure modes for this exposure barrier include:

- Changing subsurface conditions (e.g., unanticipated influx of moisture to the subsurface) could reduce the efficiency of soil vapor extraction or mobilize contaminants.
- Soil vapor extraction may not adequately remove contaminants from the vadose zone to the extent necessary to protect ground water from further degradation in a reasonable timeframe.

These uncertainties/failure modes apply to both the Current Cleanup Baseline and Risk-Based End States.

#### **4.5.2. Exposure Barrier 2 – Ground Water Extraction**

Ground water extraction has been implemented by installing numerous extraction well fields and associated ground water treatment facilities at the Livermore Site. Specifically, removing contaminants from ground water by extraction reduces risk due to:

- Ingestion by offsite human residential receptors.
- Ingestion by onsite human industrial receptors, although this is not currently a complete exposure pathway.

Under the Risk-Based End State scenario, ground water extraction would be limited to ensuring that MCLs are achieved and maintained offsite. The point of compliance would be the site boundary.

Under the Risk-Based End State scenario, ground water extraction would be continued only until onsite concentrations protective of offsite ground water (MCLs) are achieved. The point of compliance would be the site boundary. There would be no unacceptable residual risk to all identified receptors if land use remains as anticipated.

Uncertainties or failure modes for this exposure barrier include:

- Changing subsurface conditions (e.g., unanticipated recharge) affect the effectiveness of ground water extraction.
- Ground water extraction may not adequately remove contaminants to the extent required to achieve cleanup standards, or protect offsite receptors, in a reasonable timeframe.
- Changes in ground water use, including installation of water-supply wells adjacent to the Livermore Site. In addition to being receptor points for human consumption of ground

water, offsite wells could alter ground water flow patterns and result in unanticipated contaminant migration toward the wells.

These uncertainties/failure modes apply to both the Current Cleanup Baseline and Risk-Based End States.

#### **4.5.3. Exposure Barrier 3 – Institutional Controls**

The primary institutional control in place at the Livermore Site is site access restriction, enforced through fencing and security guards. A badge is required to gain entry to the site. Exposure of onsite workers to contaminants in soil (dermal contact and incidental ingestion) is controlled by restricting access to specific areas and monitoring potential exposure during construction activities. It is assumed that these controls would be maintained under both the Current Cleanup Baseline End State and Risk-Based End State scenarios. There will be no unacceptable residual risk to all identified receptors if land use remains as anticipated.

Uncertainties or failure modes for this exposure barrier include:

- In the event of a transfer of ownership of the Livermore Site to another entity, DOE would have to ensure that it met its responsibilities under Section 120 of CERCLA, which obligates DOE to clean up contamination resulting from DOE activities, or any future contamination resulting from DOE activities at the Livermore Site. In addition, no change of ownership of the site or any portion thereof could be performed by DOE without provision for continued maintenance of any containment system, treatment system, monitoring system, or other response action(s) installed or implemented.

This uncertainty/failure mode applies to both the Current Cleanup Baseline and Risk-Based End States.

## 5. References

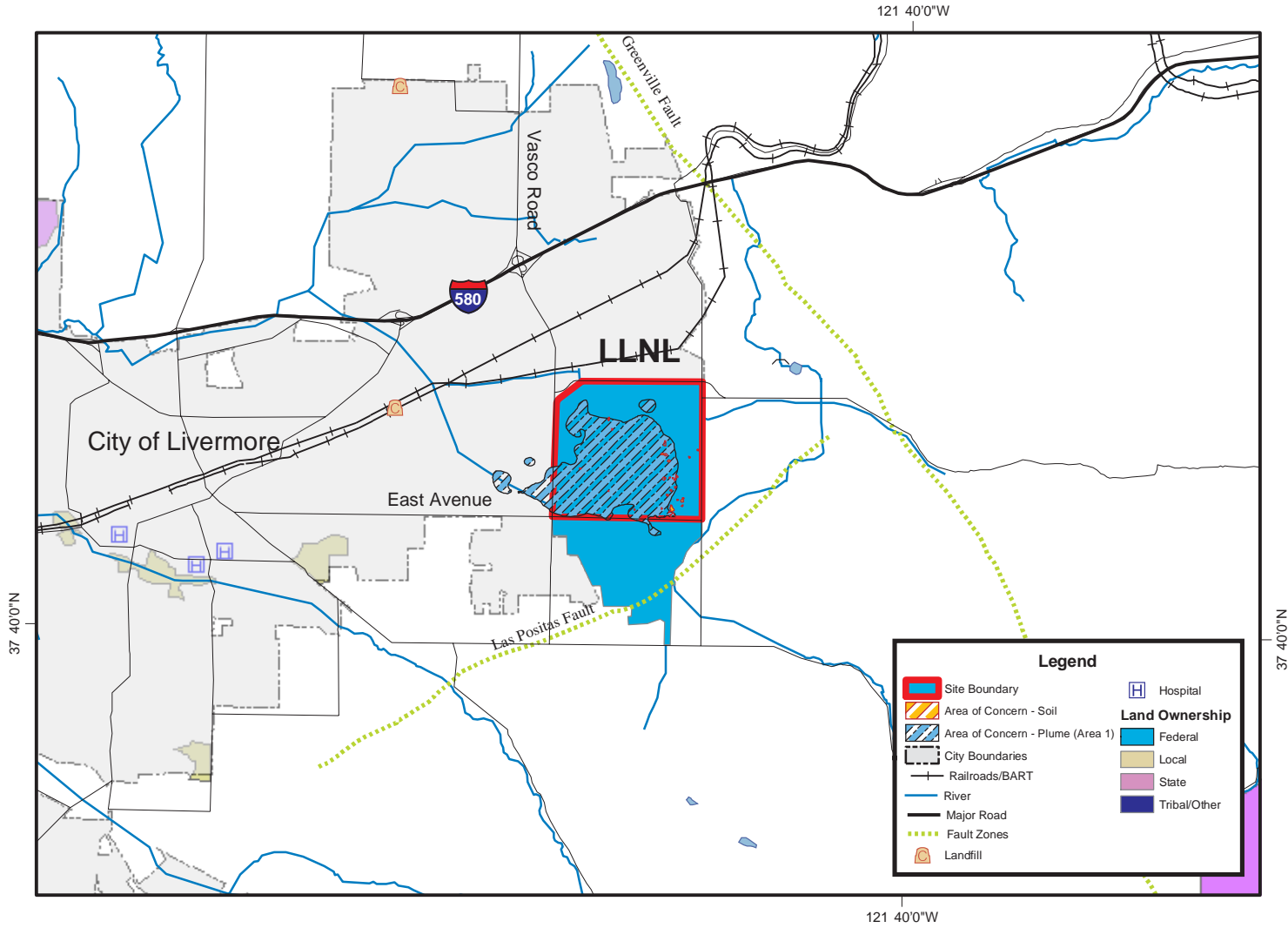
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## Figures

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Figure 2.1a,b. Regional Physical and Surface Interface - Current State and RBES



Data Sources: LLNL GIS,  
ESRI ArcGIS CD

0 0.25 0.5 1 Miles  
1:85,000

Projection: NAD 1983 State Plane  
FIPS California Zone 0403  
Lambert Conformal Conic  
January 21, 2004



Figure 2.2a,b. Regional Human and Ecological Land Use - Current State and RBES

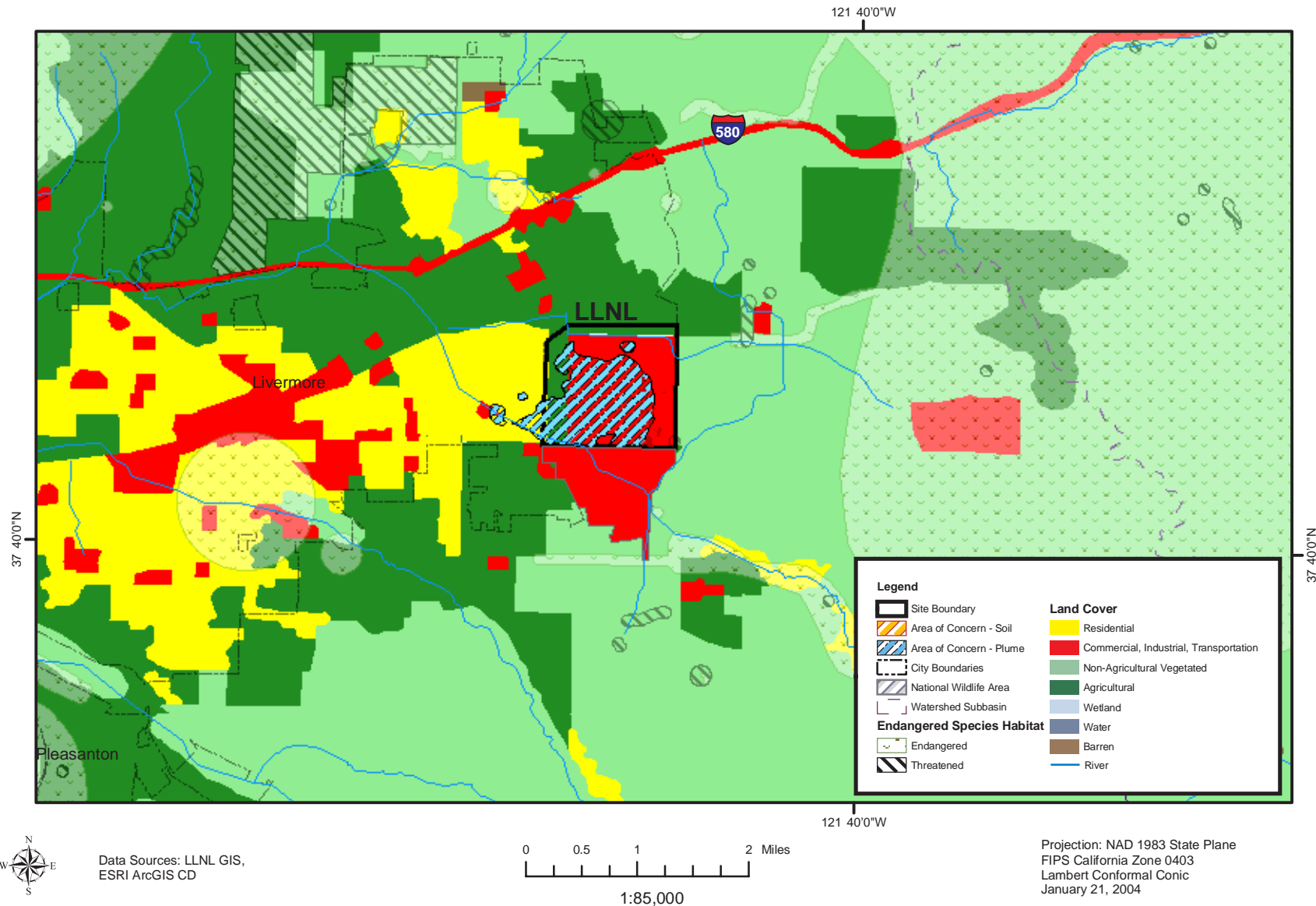


Figure 3.1a,b. Site Physical and Surface Interface - Current State and RBES

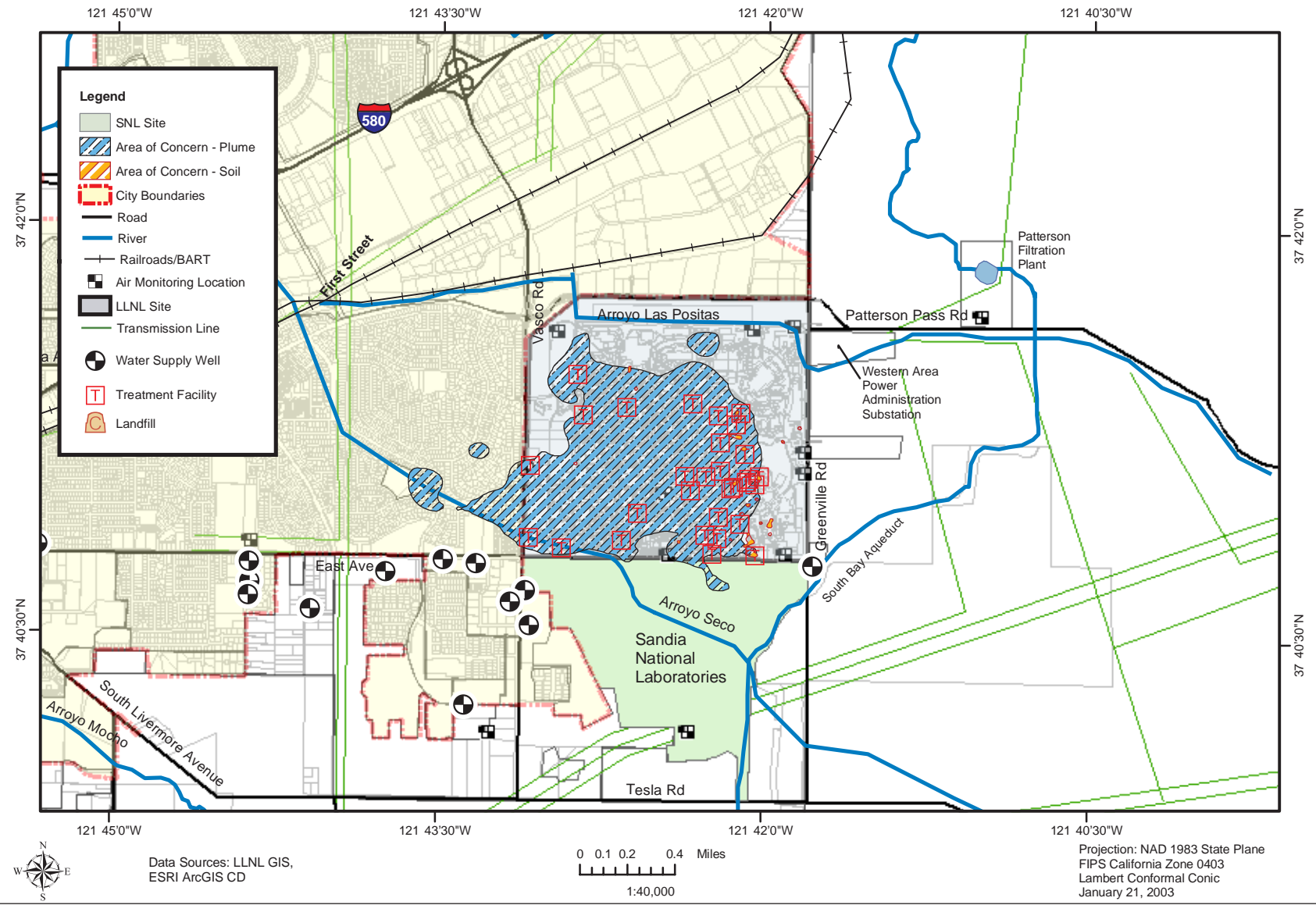


Figure 3.2a. Site Human and Ecological Land Use - Current State

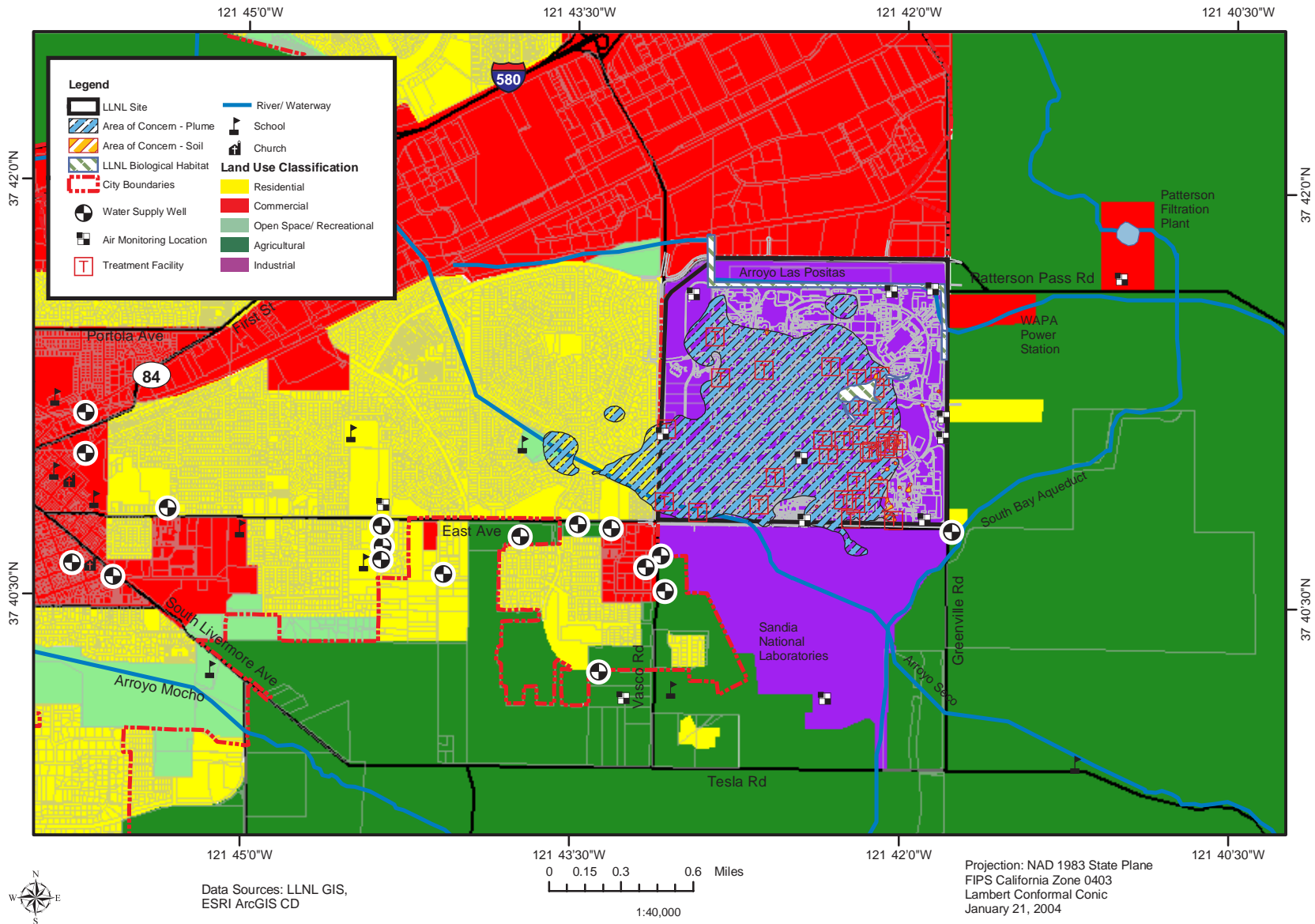


Figure 3.2b. Site Human and Ecological Land Use - RBES

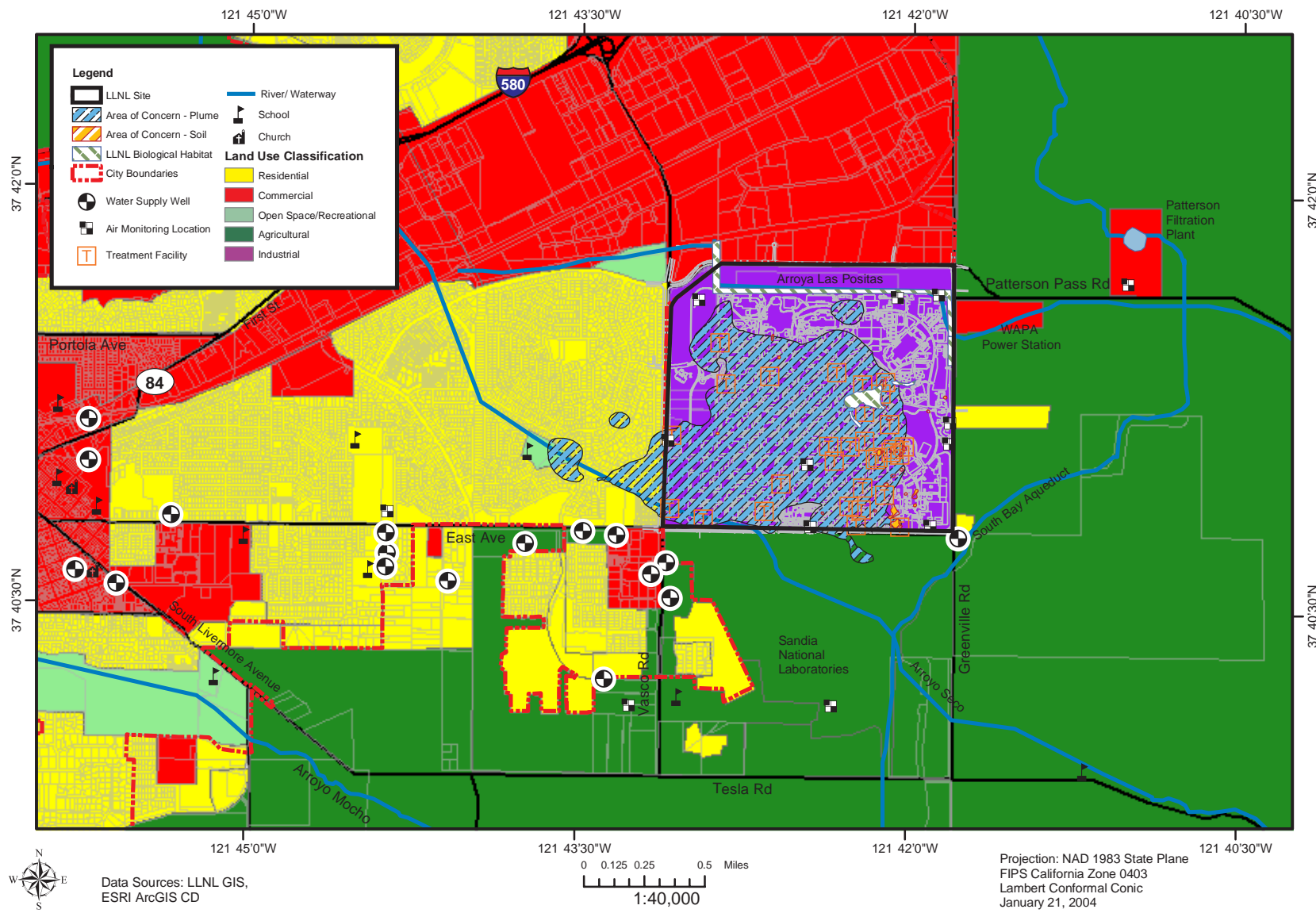
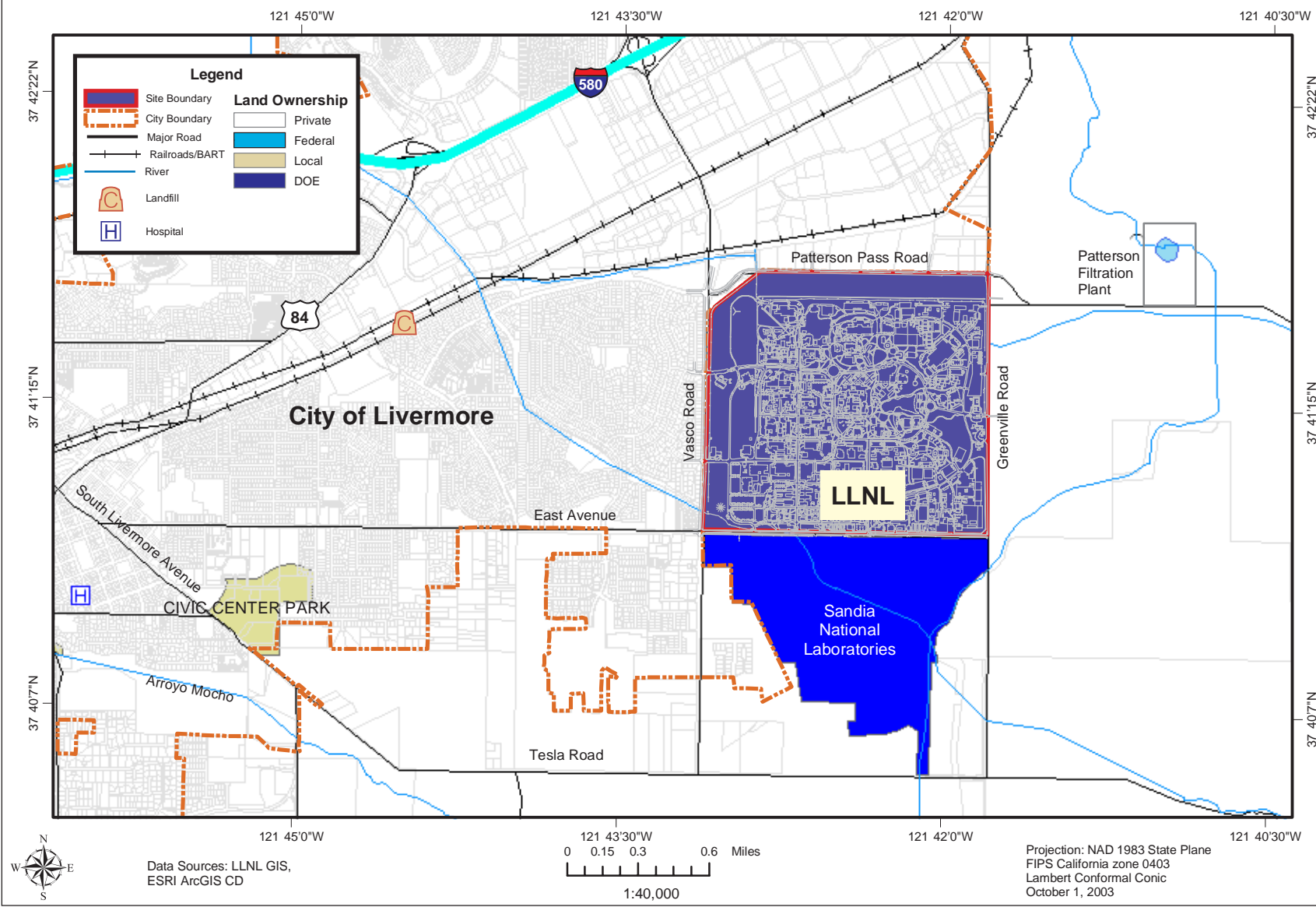


Figure 3.3a,b. Site Legal Ownership - Current State and RBES



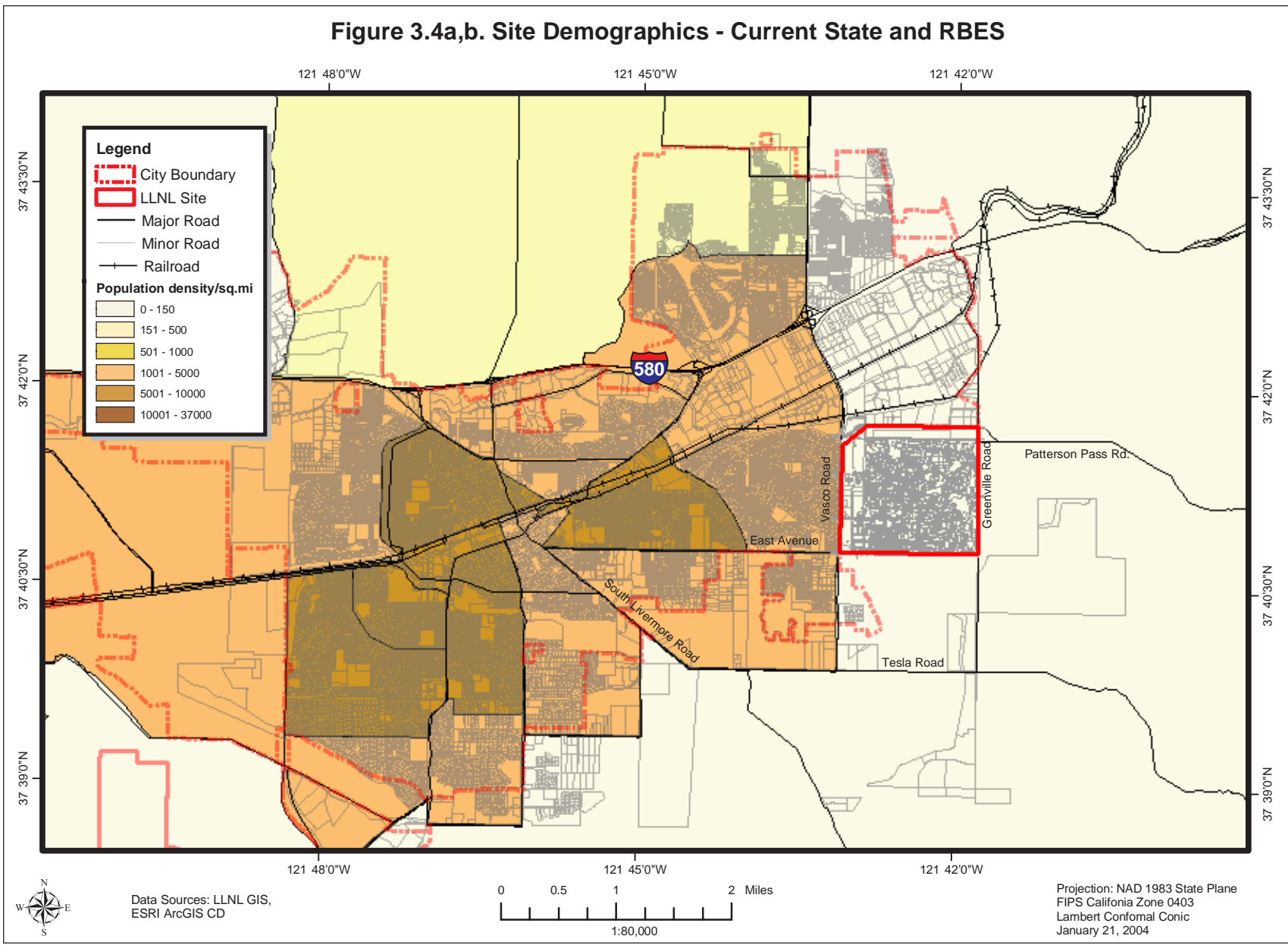


Figure 4.0a. Site-wide Hazard Map - Current State

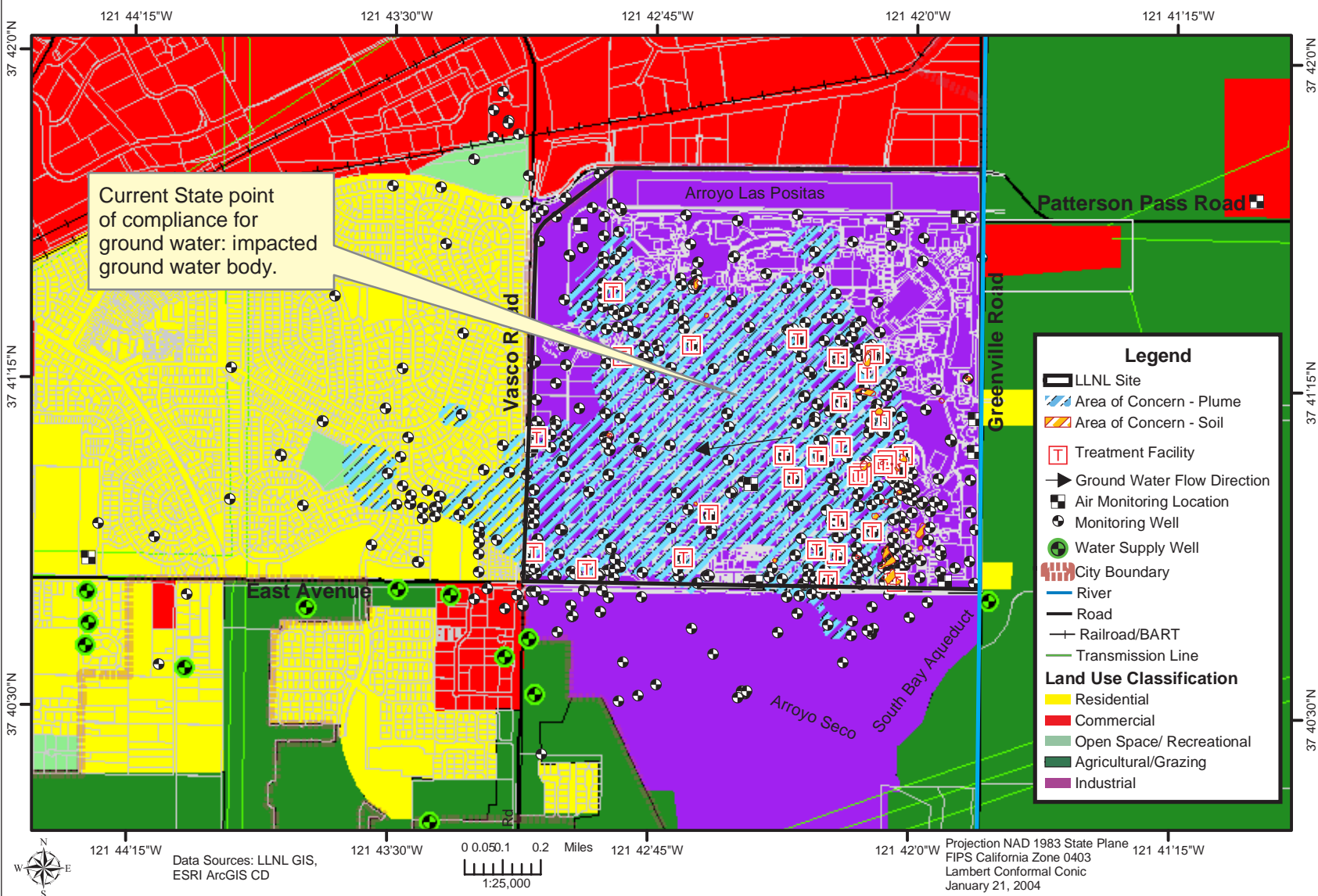
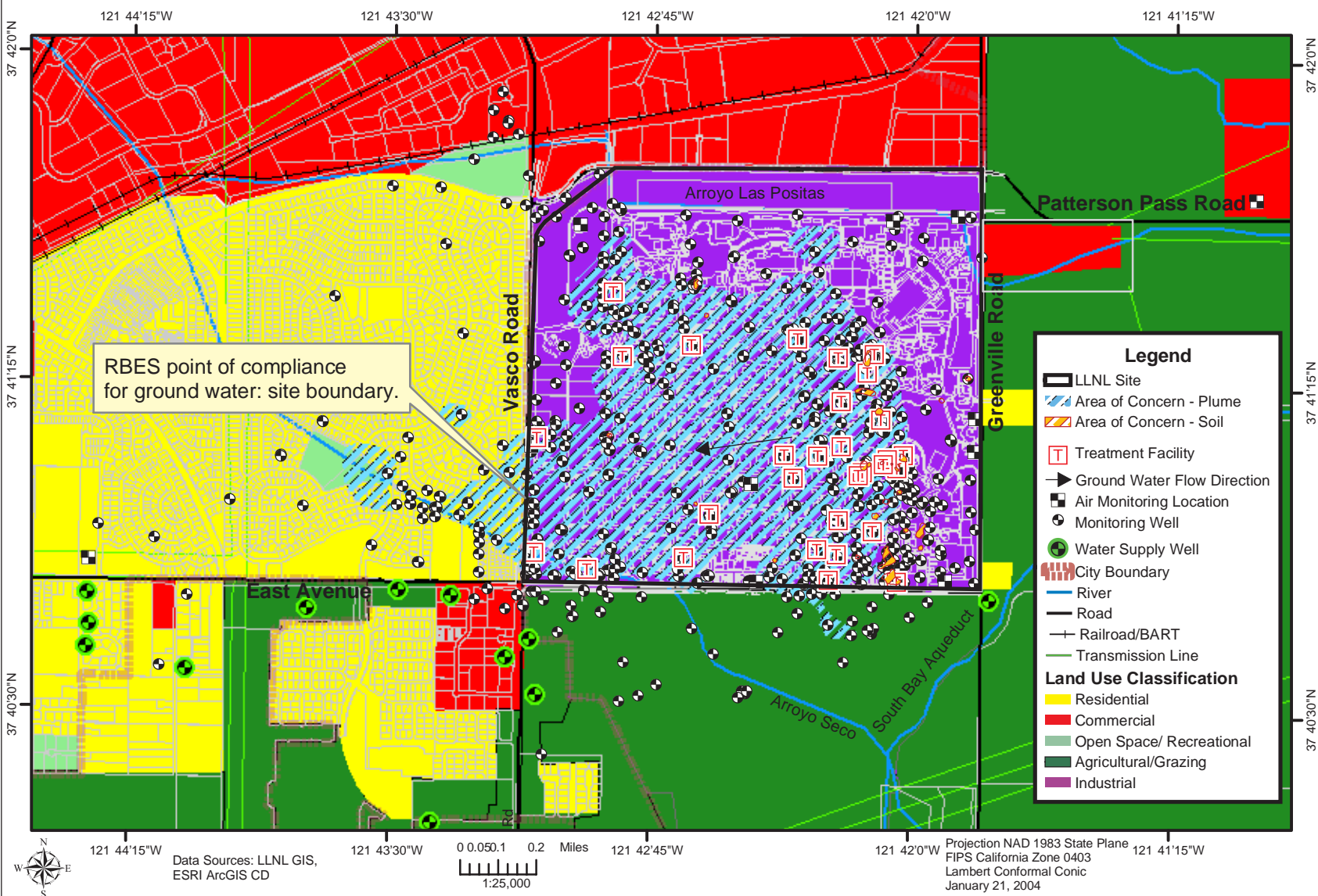


Figure 4.0b. Site-wide Hazard Map - RBES



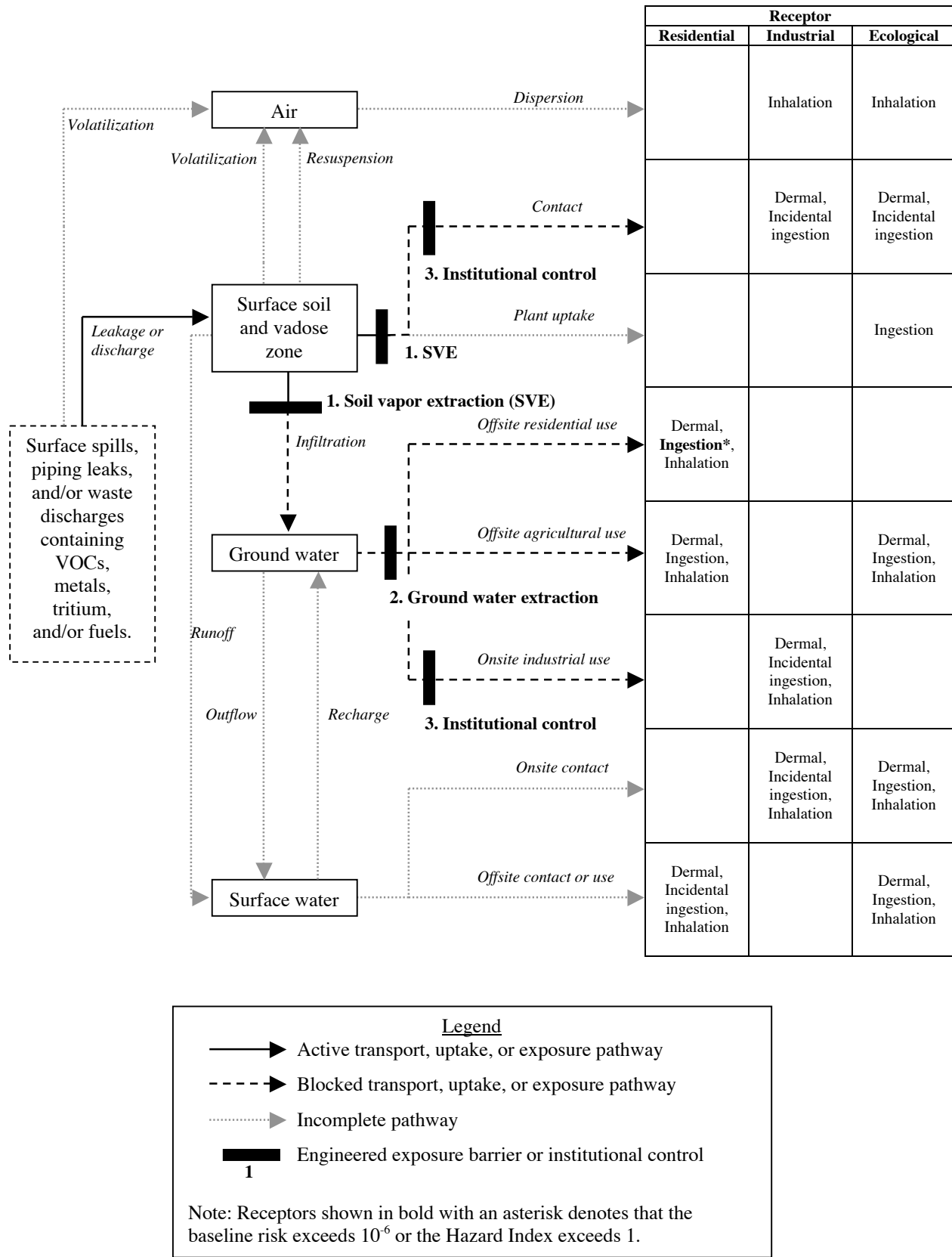


Figure 4.0a2,b2. Site-wide CSM – Current State and Risk-Based End State (page 1 of 4).

## Narrative for Figure 4.0a2,b2: Site-wide CSM – Current State and RBES.

This narrative provides a summary of information presented in Section 4 of this Risk-Based End State Vision document. Because the only difference between the Current Cleanup Baseline and the Risk-Based End States is the point of compliance for ground water, both End States are represented on a single Conceptual Site Model.

### End States

Three end state exposure scenarios are described and compared:

1. Current State – Conditions at the Livermore Site in 2003.
2. Current Cleanup Baseline End State – The end state the site will be in after implementing the existing cleanup strategy. This is based on the current and anticipated requirements of the baseline work plan documents, compliance agreements and Records of Decision, and environmental regulations. The point of compliance is the impacted ground water body, both onsite and offsite.
3. Risk-Based End State – The end state the site would be in based on planned future site use that is protective of human health and the environment for that site use. The point of compliance would be the site boundary.

The only significant strategic difference between the Current Cleanup Baseline End State and the Risk-Based End State is the point of compliance for contaminated ground water. The two end states are identical in terms of exposure of offsite receptors to contaminants from the Livermore Site, and address risk to these receptors equivalently. However, onsite cleanup of ground water under the Current Cleanup Baseline End State is intended to restore and protect ground water as a potential future resource, rather than to specifically mitigate risk. The Risk-Based End State presents a scenario based only on risk, but does not remediate onsite ground water to levels protective of ground water as a potential future resource. Ground water extraction would be limited to ensuring that MCLs are achieved and maintained offsite.

### Hazard Area Description

Initial hazardous materials releases occurred at the Livermore Site in the mid- to late-1940s when the site was the Livermore Naval Air Station. There is also evidence that localized spills, unlined landfills, and leaking tanks and impoundments contributed VOCs, fuel hydrocarbons, metals, and tritium to the ground water and unsaturated sediments in the post-Navy era. Primary sources include surface spills at facilities, piping leaks, and releases from onsite landfills. Secondary sources include the vadose zone and ground water. Maximum concentrations of contaminants are presented in Table 4.1.

### Release Mechanisms

The only release mechanism is leakage or discharge of contaminants to surface soil or the vadose zone. Volatilization of contaminants directly from the released contaminant is not applicable because contaminants have already migrated into environmental media and no active sources remain. It is assumed that the release mechanisms under the Current Cleanup Baseline End State and Risk-Based End State exposure scenarios are equivalent.

### Transport Mechanisms

The only transport mechanism is infiltration of contaminants from the vadose zone to ground water. It is assumed that the transport mechanisms under the Current Cleanup Baseline End State and Risk-Based End State exposure scenarios are equivalent.

### Exposure Mechanisms and Receptors

In the baseline risk assessment, all potential exposure mechanisms and receptors were considered. Exposure mechanisms and receptors for which no unacceptable risk or hazard was identified in the baseline risk assessment are not discussed further. Unacceptable risk or hazard was identified for ingestion of contaminated ground water by offsite residential receptors. Unacceptable risks were identified at hypothetical water-supply wells that could be installed at the site boundary. Under the best-estimate exposure scenario, the greatest incremental cancer risk is seven in ten million ( $7 \times 10^{-7}$ ), which is associated with a well 2 miles west of the Livermore Site that is in the path of the plume containing the highest concentrations of 1,1-DCE (Layton et al., 1990). Under the health-conservative exposure scenario, the incremental cancer risks are on the order of one in one thousand ( $10^{-3}$ ) to one in one million ( $10^{-6}$ ) for all wells. The highest predicted risk, two in one thousand ( $2 \times 10^{-3}$ ), is for a hypothetical well about 250 feet west of the Livermore Site. However, no such wells have been constructed to date or are planned for installation prior to cleanup. The most conservative of the health-conservative scenarios (i.e.,  $2 \times 10^{-3}$  incremental risk) is the scenario prescribed by U.S. EPA for the Livermore Site.

Under the best-estimate exposure scenario, the greatest hazard quotient is  $1.4 \times 10^{-3}$ , which is for a hypothetical well 2 miles west of the Livermore Site in the path of the plume containing the highest concentrations of carbon

tetrachloride. Under the health-conservative exposure scenario the hazard quotients are on the order of  $10^{-2}$  to  $10^{-1}$  for all wells. The highest predicted hazard quotient (0.8) is for a hypothetical well that is 250 feet west of the Livermore Site.

Under the health-conservative no-remediation scenario, the maximum additional cancer risk is two in one thousand ( $2 \times 10^{-3}$ ) for a lifetime exposure to contaminants in water from a potential monitor well drilled 250 feet west of the Livermore Site. The hazard index calculated for this scenario is 1. Because no drinking water wells are likely to be drilled in the area 250 feet west of the Livermore Site, the risk was also calculated based on a lifetime exposure to well water derived from downtown Livermore using the health-conservative assumptions. This unlikely scenario results in a maximum additional cancer risk of one in one thousand ( $1 \times 10^{-3}$ ) and a hazard index of 1. The hazard index of 1 for the health-conservative scenario indicates that there is some potential for non-carcinogenic health effects if the very conservative assumptions of the health-conservative scenario were ever realized, and if there was an additive effect of all the individual compounds. The health-conservative risks exceed the EPA one in ten thousand to one in ten million ( $1 \times 10^{-4}$  to  $1 \times 10^{-7}$ ) acceptable risk range for Superfund sites.

It is assumed that exposure mechanisms and receptors under the Current Cleanup Baseline and Risk-Based End State exposure scenarios are equivalent.

### **Remediation and Mitigation**

#### *Exposure Barrier 1 - Soil Vapor Extraction*

Soil vapor extraction has been implemented at the Livermore Site to protect ground water from potential or further degradation due to downward migration of contaminants from the vadose zone. Protection of ground water leads to mitigation of risk to onsite and offsite receptors through a ground water exposure pathway.

Under the Current Cleanup Baseline End State scenario, onsite soil vapor extraction would be continued until vadose zone concentrations protective of onsite and offsite ground water are achieved, although there are no established vadose zone cleanup standards for the Livermore Site.

Under the Risk-Based End State scenario, onsite soil vapor extraction would be continued only until concentrations protective of offsite ground water are achieved. The time or cost remaining to achieve this objective has not been determined. There would be no risk to all identified receptors if land use remains as anticipated.

Since there is no identified offsite vadose zone contamination, there will be no residual risk to all identified receptors if land use remains as anticipated under both the Current Cleanup Baseline End State and the Risk-Based End State.

Uncertainties or failure modes for this exposure barrier include:

- Changing subsurface conditions (e.g., unanticipated influx of moisture to the subsurface) could reduce the efficiency of soil vapor extraction or mobilize contaminants.
- Soil vapor extraction may not adequately remove contaminants from the vadose zone to the extent necessary to protect ground water from further degradation in a reasonable timeframe.

These uncertainties/failure modes apply to both the Current Cleanup Baseline and Risk-Based End States.

#### *Exposure Barrier 2 - Ground Water Extraction*

Ground water extraction has been implemented by installing numerous extraction well fields and associated ground water treatment facilities at the Livermore Site. Specifically, removing contaminants from ground water by extraction reduces risk due to:

- Ingestion by offsite human residential receptors.
- Ingestion by onsite human industrial receptors, although this is not currently a complete exposure pathway.

Under the Current Baseline End State scenario, ground water extraction would be continued until MCLs are achieved both onsite and offsite. The point of compliance is the impacted ground water body. There will be no unacceptable residual risk to all identified receptors if land use remains as anticipated.

Under the Risk-Based End State scenario, ground water extraction would be limited to ensuring that MCLs are achieved and maintained offsite. The point of compliance would be the site boundary. There would be no unacceptable residual risk to all identified receptors if land use remains as anticipated.

Uncertainties or failure modes for this exposure barrier include:

- Changing subsurface conditions (e.g., unanticipated recharge) affect the effectiveness of ground water extraction.
- Ground water extraction may not adequately remove contaminants to the extent required to achieve cleanup standards, or protect offsite receptors, in a reasonable timeframe.

- Changes in ground water use, including installation of water-supply wells adjacent to the Livermore Site. In addition to being receptor points for human consumption of ground water, offsite wells could alter ground water flow patterns and result in unanticipated contaminant migration toward the wells.

These uncertainties/failure modes apply to both the Current Cleanup Baseline and Risk-Based End States.

*Exposure Barrier 3 - Institutional Controls*

The primary institutional control in place at the Livermore Site is site access restriction, enforced through fencing and security guards. A badge is required to gain entry to the site. Exposure of onsite workers to contaminants in soil (dermal contact and incidental ingestion) is controlled by restricting access to specific areas and monitoring potential exposure during construction activities. It is assumed that these controls would be maintained under both the Current Cleanup Baseline End State and Risk-Based End State scenarios. There will be no unacceptable residual risk to all identified receptors if land use remains as anticipated.

Uncertainties or failure modes for this exposure barrier include:

- In the event of a transfer of ownership of the Livermore Site to another entity, DOE would have to ensure that it met its responsibilities under Section 120 of CERCLA, which obligates DOE to clean up contamination resulting from DOE activities, or any future contamination resulting from DOE activities at the Livermore Site. In addition, no change of ownership of the site or any portion thereof could be performed by DOE without provision for continued maintenance of any containment system, treatment system, monitoring system, or other response action(s) installed or implemented.

This uncertainty/failure mode applies to both the Current Cleanup Baseline and Risk-Based End States.

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## Tables

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**Table 1. Current maximum concentrations of selected contaminants in ground water at the LLNL Livermore Site.**

Contaminant	Maximum current concentration	Maximum Contaminant Level	Units
1,1-Dichloroethene (1,1-DCE)	600	6	µg/L
Benzene	120	1	µg/L
Carbon tetrachloride	120	0.5	µg/L
Chloroform	190	100 <sup>a</sup>	µg/L
Chromium	3,500	50	µg/L
Ethylbenzene	240	300	µg/L
Hexavalent chromium	6.3	None	µg/L
Tetrachloroethene (PCE)	4,500	5	µg/L
Toluene	860	150	µg/L
Total xylene isomers	1,400	1,750	µg/L
Trichloroethene (TCE)	200,000	5	µg/L
Tritium	469,000	20,000	pCi/L

<sup>a</sup> Total trihalomethanes

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**Attachment A:**  
**Risk-Based End State Vision Variance Report for**  
**Lawrence Livermore National Laboratory**  
**Livermore Site**

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## **Attachment A:**

### **Risk-Based End State Vision Variance Report for Lawrence Livermore National Laboratory – Livermore Site**

This Attachment describes the variance between the Current Cleanup Baseline End State and the Risk-Based End State for the Livermore Site.

#### **Variance 1: Point of Compliance for Ground Water**

##### *Description of Variance:*

The Current Cleanup Baseline End State assumes that all ground water contaminated by Livermore Site activities must ultimately be remediated in a manner consistent with current environmental regulations and existing compliance agreements, both onsite and offsite. The impacted ground water body is assumed to be the point of compliance. The Risk-Based End State Vision assumes that the site boundary would be the point of compliance for contaminants in ground water. The Risk-Based End State Vision is not consistent with Federal and State environmental regulations and existing compliance agreements in terms of onsite cleanup of ground water.

##### *Variance Impacts:*

An analysis of the time, cost, and scope to implement the Risk-Based End State Vision is not available. Without performing this analysis, it is not possible to compare these parameters to those for the Current Cleanup Baseline End State.

##### *Barriers to Achieving a Risk-Based End State:*

California Regional Water Quality Control Board Resolution 92-49, Section III.G., requires that cleanups be conducted in a manner that “promotes the attainment of either background water quality, or the best water quality that is reasonable if background levels of water quality cannot be restored.” The Board does not recognize a site boundary, per se, as an alternate point of compliance. DOE has accepted Resolution 92-49 as an Applicable or Relevant and Appropriate Requirement for the cleanup of the Livermore Site.

The Risk-Based End State is also contrary to enforcement documents signed by the DOE, the U.S. Environmental Protection Agency, the California Department of Toxic Substances Control, and the California Regional Water Quality Control Board, specifically the Record of Decision for the Livermore Site, that sets ground water cleanup standards as Maximum Contaminant Levels, with the point of compliance being the impacted ground water body. In comments received by DOE on the Draft Risk-Based End State Vision, the regulatory agencies, local governments, and the public have stated that they expect DOE to honor the terms of these existing enforcement documents.

##### *Recommendations:*

Specific recommendations to address this Variance will be developed during preparation of the final Risk-Based End State Vision. Resolution of this issue will likely require EM-1 involvement with State regulators, EPA Region IX, local government, and the community.



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